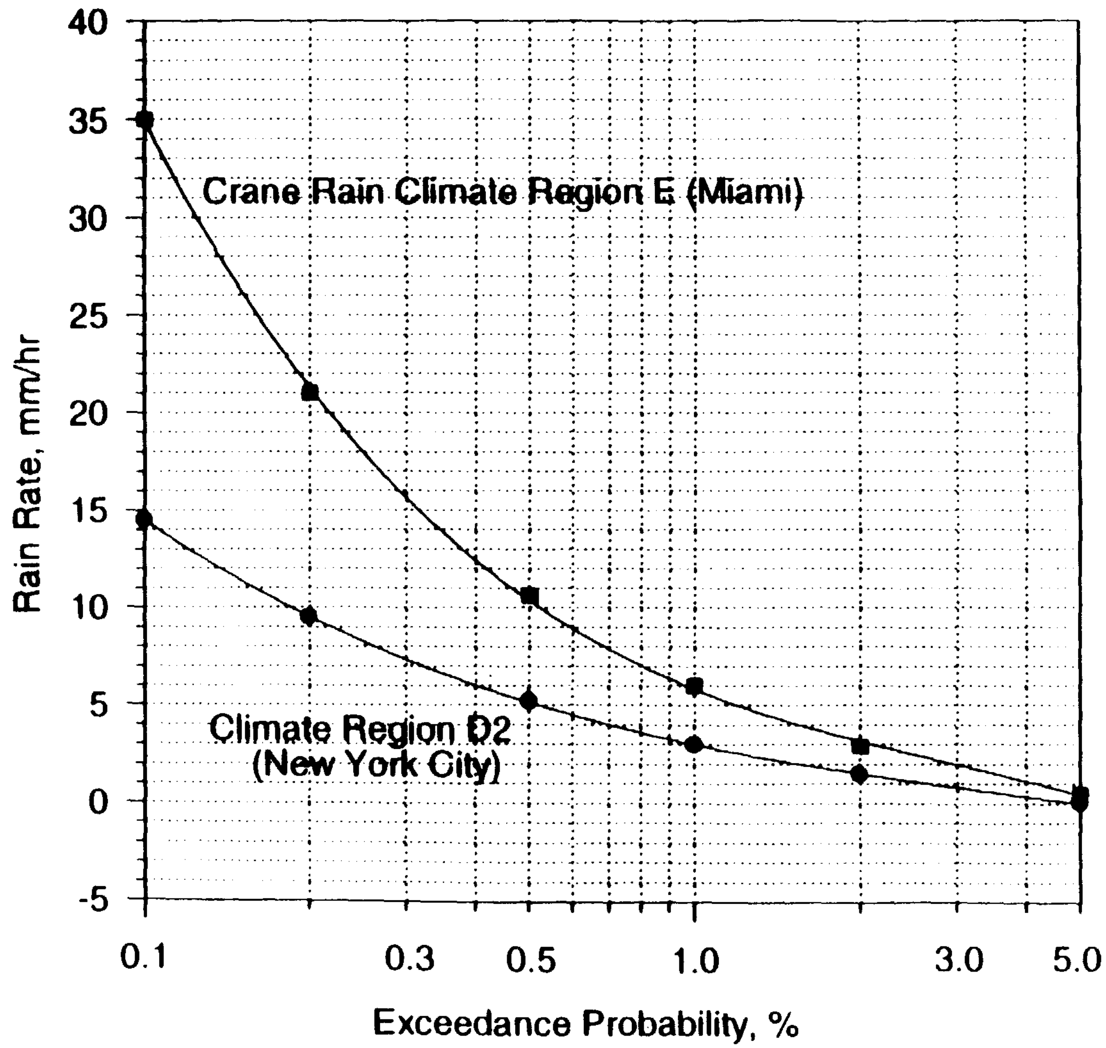
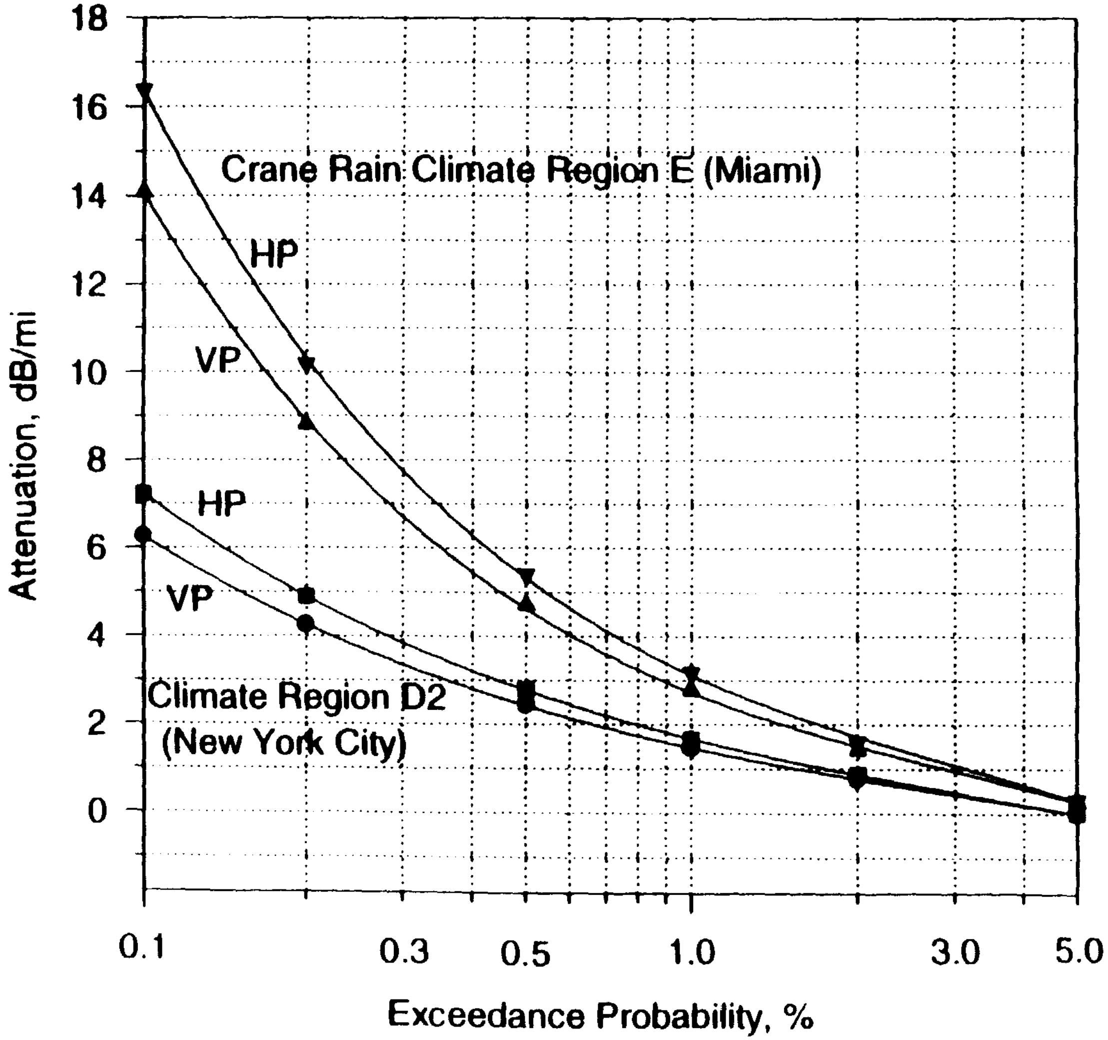
Rain Rate Statistics in NYC and Miami



Attenuation Statistics at 41.5 GHz



Foliage Loss

- Foliage introduces significant attenuation at all microwave/millimeter bands

- Measurements by Schwering et al. at 9.6, 28.8, 57.6 GHz through leafy and non-leafy foliage found :
  - Leafy conditions :
    - 28.8 GHz exhibits sharply higher attenuation than 9.6 GHz
    - 57.6 GHz exhibits slightly higher attenuation than 28.8 GHz (~10%)
  - Non-leafy conditions :
    - Incrementally higher attenuation with increasing frequency (~10% each step)
  - In all cases, foliage loss by two trees > 10 dB, and usually > 20 dB
  - *Reference:* F. Schwering, E. J. Violette, R. H. Espeland, "Millimeter-wave propagation in vegetation: Experiments and Theory", *IEEE Trans. Geoscience and Remote Sensing*, Vol 26, No 3, May 1988.

- Foliage loss at 38 and 42 GHz should not differ appreciably from the loss at 28 GHz; Loss at 15.3 GHz may be slightly less than at 28 GHz

- At all bands under consideration very little intervening foliage will be tolerable

Diffractive Shadowing Loss

- Loss due to shadowing by obstructions such as buildings increases with frequency;

- A comparison scenario: LOS blocked by 0.28m; 30m from receiver; 1km path
  - 15.3 GHz Shadow Loss = 8.9 dB 1.4 dB Improvement
  - 28.5 GHz Shadow Loss = 10.3 dB [Baseline]
  - 38.0 GHz Shadow Loss = 10.8 dB 0.5 dB Degradation
  - 41.5 GHz Shadow Loss = 11.1 dB 0.8 dB Degradation
  - ***2 dB shadowing loss may be gained back at 42 GHz by moving the subscriber antenna only 13 cm***

  - *Computed via Fresnel-Kirchoff 'infinite knife-edge' diffraction theory*

- At these frequency bands diffractive shadowing is a strong effect, *very* sensitive to small amounts of blockage
  - >> Variation between the bands is not large - comparable to small displacements of receiver antenna

Near-Field Scattering

- Building surfaces
  - Scatter from a flat surface may be viewed as radiation from an aperture
  - Large building surfaces produce near-field scatter over distances up to 100's of meters (at both 28 and 42 GHz)
  - Subscribers therefore may be in the near field of building reflections

  Reference: M. O. Al-Nuaimi and M. S. Ding, "Prediction models and measurements of microwave signals scattered from buildings", *IEEE Trans. Antennas Propagat.*, Vol 42, No 8, August 1994.

- Impact to subscribers relying on building reflection as signal source: The pattern of re-radiation of energy from the building surface will be more unpredictable and dependent on distance from surface

- No impact to LOS subscribers

- No significant dependence on frequency band

Near-Field Scattering

- Suite 12 Hub Antenna
  - Circular horn, 12 inch diameter
  - Far field is 12 inches from feed, 6 inches from edge of horn
  - Therefore, no near-field scatter effects expected at hub transmitter

- Subscriber antenna
  - Parabolic reflector, 8 inch nominal diameter
  - Far-field begins 0.96m (at 28 GHz), or 1.45m (at 42 GHz) from antenna
  - Therefore, scatterers will normally be in the far field of the subscriber antenna

- The near-field of each antenna is therefore small enough to be neglected

Impact of Hub Antenna Pattern

- Suite 12 claims hub transmitters typically will be atop 12-15 story buildings
- Patterns are provided for a TI antenna and a Suite 12 antenna

	Effective Gain (Reduced Loss) Ref'd to 3 mi Cell Edge			150' Hub Tower			250' Hub Tower		
Horizontal Distance	Path Gain	Rain Gain	Total Gain	Angle to Ground	Ste 12 Pattern	TI Pattern	Angle to Ground	Ste 12 Pattern	TI Pattern
2000 ft	18.0	11.4	29.4	4.3°	5 dB	5 dB	7.1°	8 dB	9 dB
1500 ft	20.5	11.8	32.3	5.7°	6 dB	7 dB	9.5°	19 dB	12 dB
1000 ft	24.0	12.2	36.2	8.5°	10 dB	10 dB	14.0°	<25 dB	23 dB
500 ft	30.0	12.6	42.6	16.7°	<25 dB	24 dB	26.6°	<30 dB	<34 dB
100 ft	44.0	12.9	56.9	56.3°	<40 dB	40 dB	68.2°	<40 dB	<40 dB

- Ste 12 Pattern: Boresight gain = 12 dB
- TI Pattern: Boresight gain = 14 dB

Impact of Hub Antenna Pattern

- Current hub transmitter antenna gain spec is 10 dB
- Calculations were performed using antenna patterns with boresight gains of 12 and 14 dB
- Pattern loss for subscribers at ground level, using transmitter heights of 150 and 250 ft, is always less than the reductions in path loss and rain loss relative to the cell edge
- Therefore, increasing the hub transmitter antenna gain is not expected to result in loss of service to near-in subscribers

HUGHES

41 GHz EQUIPMENT IN THE UNITED STATES - AVAILABILITY AND COSTS

41 GHz EQUIPMENT IN THE UNITED STATES - AVALABILITY AND COSTS

- MOST ELEMENTS OF THE LMDS (HUB THROUGH SUBSCRIBER EQUIPMENT) WILL NOT CHANGE WITH A MOVE TO 41 GHz - ONLY THE RF COMPONENTS

- RF COMPONENTS
    - RF PORTION (UP-CONVERTER) OF HUB
    - HUB TRANSMITTER (TWTA OR SSPA)
    - HUB ANTENNA
    - SUBSCRIBER ANTENNA
    - RF PORTION OF SUBSCRIBER RECEIVER UNIT

MAJOR CONTRIBUTORS TO DIFFERENTIAL COST

- ALL OTHER COMPONENTS (MAJOR COST ITEMS) REMAIN THE SAME

- IMPACT OF 41 GHz RF COMPONENTS ON TOTAL LMDS SYSTEM COSTS LESS THAN 10 %

HIGH POWER AMPLIFIER (TWTA)

Company	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
ETM	Current Product - 80W 10: $75,300. 100: $68,100. 1000: $63,100. 10,000: $58,700. Current Product - 120W 10: $78,700. 100: $71,300. 1000: $66,300. 10,000: $57,500.	Add 10% to price while subtracting 20-30% from power. Potential Product - 55W 10,000: $64,600. Potential Product - 80W 10,000: $67,900.	Price quotes done with conservative learning curve. If true high quantity buying, the prices would be lower than these ROMs.
Varian	Current Product - 120W 10: $80,000.		
Logimetrics	Current Product - 120W 1: $100,000. 100: $80,000. 5000: $65,000.	Potential Product - 80W 1: $275,000. 5000: $225,000.	41 GHz requires NRE.
Hughes	Current Product - 100W 1: $65,000. 10: $62,000. 100: $53,000. 1000: $38,000. 10,000: $25,000.	Potential Product - 65 W 1: $81,000. 10: $77,000. 100: $66,000. 1000: $48,000. 10,000: $32,000.	41 GHz requires NRE. Quantities of 1000 or more requires continuous TWT production.

SOLID STATE POWER AMPLIFIER (SSPA)

Company	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
DBS Microwave	Potential Product - 1W 1-4: $14,500. 100: $11,000. 1,000: $3,500. 10,000: $2,500.	Potential Product - 1W 1-4: $17,500. 100: $13,000. 1000: $5,500. 10,000: $4,000.	GaAs thin film design. Further cost saving by using a lower cost substrate material.
Hughes	Potential Product - 1.5W 10,000: $1,500.	Potential Product - 1.5W 10,000: $3,000.	

UP CONVERTER

Company	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
DBS Microwave	Potential Product 1-4: $4,425. 100: $3,300. 1000: $1,100. 10,000: $675.	Potential Product 1-4: $5,000. 100: $3,795. 1000: $1375. 10,000: $775.	GaAs thin film design. IF is 1 GHz. IF amplifier, LO multiplier, mixer, power amplifier.
Hughes	Potential Product 10,000: $300.	Potential Product 10,000: $300.	IF is 1 GHz. Filter, mixer, LO buffer amplifier, RF amplifier. Synthesizer provides LO and IF.

CELL SITE ANTENNA

Company	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
Prodelin	Potential Product 10: $3,000. 100: $800. 1,000: $150. 10,000: $50. 100,000: $42. (Assume tool used for 10k & 100k)	Potential Product Same price as 28 GHz band. Higher frequency antenna requires less material, but product is more difficult to manufacture.	NRE Engineer Design: $50,000. NRE High Volume Manufacturing Tool: $60,000.

SUBSCRIBER RECEIVER UNIT

Company	27.5 - 29.5 GHz	40.5 - 42.5 GHz	Issues
Alpha (Subscriber Receiver Unit)	Flat plate antenna with RF to baseband converter $150 (large quantities). Requires baseband to TV Converter $200 (large quantities).		
Endgate (Subscriber Receiver Unit)	Flat plate antenna with transceiver for Digital, analog FM or AM: $400-$600 (large quantities). FM requires $200 converter. Digital requires $450 converter. AM requires no converter.	RF equipment cost increase 15-20% for 1-3 years. After third year, costs will equal 28 GHz.	
GEC Marconi (Subscriber Receiver Unit)		6 inch reflector with RF to L-band converter: $70 (large quantities). Requires L-band converter box ($130-$260).	MVDS receiver subscriber unit.
Prodelin (Antenna Only)	Potential Product $10.-15. (Assume large production quantities.)	Same price as 28 GHz band. Higher frequency antenna requires less material, but product is more difficult to manufacture.	DBS antenna cost is less than $15., and LMDS requires smaller antenna.

CUMULATIVE COST SUMMARY

		HPA or TWTA	Up Converter
1	ROM price range for 28 GHz at 10,000 piece part	\$25,000-\$65,000	\$300-\$675
2	28 GHz average ROM cost for 10,000	\$50,600	\$490
3	ROM price range for 41 GHz at 10,000 piece part	\$32,000-\$225,000	\$300-\$775
4	41 GHz average ROM cost for 10,000	\$97,400.	\$540
5	% cost increase due to frequency change	92.5%	10%
6	% 28 GHz equipment cost to 28 GHz RF cell site start up cost (RF equipment, install and 1 year warranty) assuming dual redundancy	25.3%	0.245%
7	% Increase 41 GHz equipment cost increase to 28 GHz RF cell site start up cost	23.4%	0.0245%
8	% Increase 41 GHz equipment cost increase to total lifetime cell site cost (real estate, back-bone communications infrastructure equipment, RF equipment, warranty, and long term maintenance)	7.02%	0.00735%

% INCREASE FOR OTHER 41 GHz RF COMPONENTS: 0.00%

TOTAL % INCREASE FOR ALL 41 GHz RF COMPONENTS: 7.03%

COMPONENT COST FACTOR DUE TO ALL 41 GHz RF COMPONENTS: 1.07

TOTAL 41 GHz COMPONENT COST FACTOR RANGE: 1.05 - 1.10

40 GHz Microwave Equipment, Status and Availability in Europe

Scientific Generics

Dr. Teddy O'Connell

MVDS - History

- Aug 1989, the UK RA selected 40.5 GHz to 42.5 GHz band for MVDS
- In 1990, CEPT recommended that the band 40.5 - 42.5 GHz be adopted into domestic allocation for MVDS
- MVDS working group established to create necessary technical, planning and licensing rules for analog MVDS
- MPT 1550 specification created in Sept 1993. This has been drafted to provide the maximum commonality between MVDS and ASTRA satellite DTH receivers.
- In Europe 11 countries have designated the 40 GHz band for MVDS and 9 plan to do so
- In 1994 working group re-convened to develop specification for digital compressed TV with voice and data return links

UK MVDS - Current Status

- EUROBELL - local delivery franchise awarded for 100K homes in West Kent, UK
    - approx 35 cells, average 1500 homes per cell
    - Local Delivery - full interactive service to 16,200 homes
    - Regional Delivery - Microwave relay of standard satellite channels
    - Service roll-out 1996-1998, initially using Philips equipment
- At present there are also a number of other MVDS bids in preparation. These will be submitted before end of March
- MVDS radio equipment available in production from Philips Microwave and GEC Marconi by August 1995

UK MVDS - Current Status

- Currently looking towards Digital MVDS
  - Greater spectral utilisation
  - better/more stable picture quality
  - greater interactive capability e.g. Video on Demand
  - possibility of more efficient cell re-use

- RA Digital MVDS working group established in 1994

UK MVDS - Current Status

- PROPOSED DIGITAL MVDS DESIGN

- To achieve compatability with DTH systems
  - MPEG-2 compression techniques
  - QPSK modulation employed
  - 29.5 MHz channel spacing

- Back-channel method: i.e. provide return channel at approx 64 - 640 KB/s

UK MVDS - Current Status

- PROPOSED DIGITAL MVDS DESIGN
  - MPEG-2 compression techniques => 2MB/s - 6MB/s per programming channel

    Thus can contain approx 24MB/s in 1 channel

    => 4 to 12 programming channels in 29.5 MHz

    Total no. of channels is: 128 (4x32) to 384 (12x32)

    in 1 GHz

Current MVDS Equipment

- Philips Microwave - significant investment in 40 GHz radio equipment
  - approx 10 man years in developing complete system

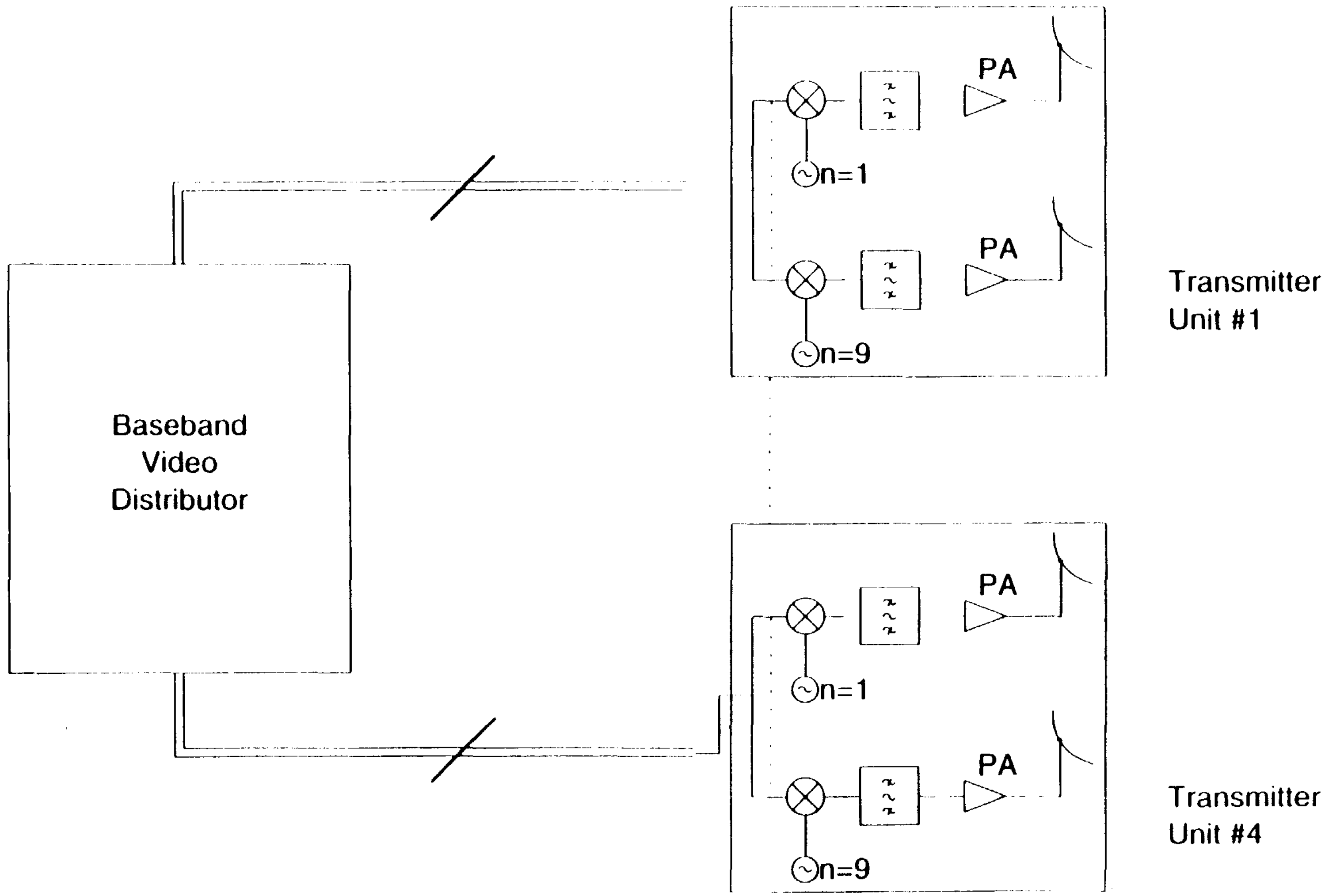
- Demo equipment available now
- Production quantities by August 1995

- Equipment is based on achieving as much commonality as possible with existing DTH front end receivers and indoor IF demodulator units

Current MVDS Equipment

- **PHILIPS Transmitter Unit specification**
  - **4 transmitter units, each with 8+1 (redundant) transceiver**
  - **Redundant transmitter on Hot Standby (200 MHz bandwidth)**
  - **Seperate transmitter for each channel**
  - **PA technology MMIC GaAs pHEMT - Power is 23 dBm per channel**
    - **cost approx £800 each in volume**
  - **By 1996 transmitter powers of 1 Watt per channel could be available**
  - **Horn Antenna for each channel => 15 dB gain**
  - **Cost estimate: £33,000-£57,000 for transmitter station**

Philips Transmitter Unit



GENERICS